L Number	Hits	Search Text	DB	Time stamp
22	334	(first or second) with segment and data and seismic	USPAT; US-PGPUB	2004/01/21 14:31
23	11	(first or second) with segment and data and seismic with sweep	USPAT; US-PGPUB	2004/01/21 14:40
24	23	noise with remove$3 and (first or second) with segment and data and seismic	USPAT; US-PGPUB	2004/01/21 14:41
25	1	cascade$3 with sweep and noise with remove$3 and (first or second) with segment and data and seismic	USPAT; US-PGPUB	2004/01/21 14:41
26	2	cascade$3 with sweep and noise and remove$3 and (first or second) with segment and data and seismic	USPAT; US-PGPUB	2004/01/21 14:43
27	4	cascade$3 with sweep and (first or second) with segment and data and seismic	USPAT; US-PGPUB	2004/01/21 16:31
28	1	window with cascade$3 with sweep and (first or second) with segment and data and seismic	USPAT; US-PGPUB	2004/01/21 16:28
29	1	variphase with gather	USPAT; US-PGPUB	2004/01/21 16:29
30	3	cascade$3 with sweep and (first or second) with segment and data and seismic and window	USPAT; US-PGPUB	2004/01/21 16:34
31	3	cascade$3 with sweep and (first or second) with segment and data and seismic and window and noise	USPAT; US-PGPUB	2004/01/21 16:34

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L Number	Hits	Search Text	DB	Time stamp
22	334	(first or second) with segment and data and seismic	USPAT; US-PGPUB	2004/01/21 14:31
23	11	(first or second) with segment and data and seismic with sweep	USPAT; US-PGPUB	2004/01/21 14:40
24	23	noise with remove$3 and (first or second) with segment and data and seismic	USPAT; US-PGPUB	2004/01/21 14:41
25	1	cascade$3 with sweep and noise with remove$3 and (first or second) with segment and data and seismic	USPAT; US-PGPUB	2004/01/21 14:41
26	2	cascade$3 with sweep and noise and remove$3 and (first or second) with segment and data and seismic	USPAT; US-PGPUB	2004/01/21 14:43
27	4	cascade$3 with sweep and (first or second) with segment and data and seismic	USPAT; US-PGPUB	2004/01/21 16:31
28	1	window with cascade$3 with sweep and (first or second) with segment and data and seismic	USPAT; US-PGPUB	2004/01/21 16:28
29	1	variphase with gather	USPAT; US-PGPUB	2004/01/21 16:29
30	3	cascade$3 with sweep and (first or second) with segment and data and seismic and window	USPAT; US-PGPUB	2004/01/21 16:34
31	3	cascade$3 with sweep and (first or second) with segment and data and seismic and window and noise	USPAT; US-PGPUB	2004/01/21 16:34

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L Number	Hits	Search Text	DB	Time stamp
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33	1	cascade$3 with sweep with window	USPAT; US-PGPUB	2004/01/21 16:44
34	10	cascade$3 with sweep and window	USPAT; US-PGPUB	2004/01/21 16:44
35	1	cascade$3 with sweep and window with rms	USPAT; US-PGPUB	2004/01/21 16:45
36	3	cascade$3 with sweep and window with (data or segment) and rms	USPAT; US-PGPUB	2004/01/21 16:46
37	1	noise with remove$4 and cascade$3 with sweep and sweep with stack$3	USPAT; US-PGPUB	2004/01/21 16:48
38	1	noise with remove$4 and cascade$3 and sweep and sweep with stack$3	USPAT; US-PGPUB	2004/01/21 16:48
39	36	noise with remove$4 and cascade$3 and sweep and sweep and stack$3	USPAT; US-PGPUB	2004/01/21 16:48
40	1	noise with remove$4 and cascade$3 with sweep and sweep and stack$3	USPAT; US-PGPUB	2004/01/21 16:48
41	1	noise with remove$4 and cascade$3 with sweep and stack$3	USPAT; US-PGPUB	2004/01/21 16:49
42	1	noise with remove$4 and cascade$3 adj sweep$3 and stack$3	USPAT; US-PGPUB	2004/01/21 16:49
43	39	noise with remove$4 and cascade$3 and sweep$3 and stack$3	USPAT; US-PGPUB	2004/01/21 16:49
44	2	noise with remove$4 and cascade$3 and sweep$3 and stack$3 and seismic	USPAT; US-PGPUB	2004/01/21 16:49

C:\APPS\EAST\Workspaces\Sweeps-First-Second- Data-Segments-Seismic-Chirp-Sweet.wsp

	U	1	Document ID	Issue Date	Pages	Title	Current OR
1	☐	☐	US 20030163260 A1	20030828	11	Method of noise removal for cascaded sweep data	702/14
2	☐	☐	US 6418079 B1	20020709	10	Method of reducing harmonic interference while using overlapping source point seismic recording techniques	367/40
3	☐	☐	US 5410517 A	19950425	17	Method for cascading sweeps for a seismic vibrator	367/75

	Current XRef	Retrieval Classif	Inventor	S	C	P	2	3	4	5
1			Moerig, Rainer et al.	☒	☐	☐	☐	☐	☐	☐
2	367/41; 367/43		Fleure, Thomas John	☒	☐	☐	☐	☐	☐	☐
3	181/108; 181/113; 367/190; 367/38; 367/40; 367/41		Andersen, Kenneth D.	☒	☐	☐	☐	☐	☐	☐

	Image Doc. Displayed	PT
1	US 20030163260	☐
2	US 6418079	☐
3	US 5410517	☐

L Number	Hits	Search Text	DB	Time stamp
22	334	(first or second) with segment and data and seismic	USPAT; US-PGPUB	2004/01/21 14:31
23	11	(first or second) with segment and data and seismic with sweep	USPAT; US-PGPUB	2004/01/21 14:32

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L Number	Hits	Search Text	DB	Time stamp
22	334	(first or second) with segment and data and seismic	USPAT; US-PGPUB	2004/01/21 14:31
23	11	(first or second) with segment and data and seismic with sweep	USPAT; US-PGPUB	2004/01/21 14:32

C:\APPS\EAST\Workspaces\Sweeps-First-Second- Data-Segments-Seismic-Chirp-Sweet.wsp

	U	1	Document ID	Issue Date	Pages	Title	Current OR
1	☐	☐	US 20030163260 A1	20030828	11	Method of noise removal for cascaded sweep data	702/14
2	☒	☐	US 20020091487 A1	20020711	23	Method of using cascaded sweeps for source coding and harmonic cancellation	702/2
3	☒	☐	US 6418079 B1	20020709	10	Method of reducing harmonic interference while using overlapping source point seismic recording techniques	367/40
4	☒	☐	US 5742740 A	19980421	23	Adaptive network for automated first break picking of seismic refraction events and method of operating the same	706/14
5	☒	☐	US 5410517 A	19950425	17	Method for cascading sweeps for a seismic vibrator	367/75
6	☒	☐	US 4809235 A	19890228	20	Method for removing doppler phase dispersion from seismic data	367/21
7	☒	☐	US 4715020 A	19871222	9	Simultaneous performance of multiple seismic vibratory surveys	367/38
8	☒	☐	US 4202048 A	19800506	59	Seismic prospecting system	367/40
9	☒	☐	US 4201972 A	19800506	67	Seismic prospecting system	367/40
10	☒	☐	US 4188611 A	19800212	56	Seismic prospecting system	367/41
11	☒	☐	US 3678454 A	19720718	9	GEOPHYSICAL SURVEYING USING FRESNEL PILOT SIGNALS	367/64

	Current XRef	Retrieval Classif	Inventor	S	C	P	2	3	4	5
1			Moerig, Rainer et al.	☒	☐	☐	☐	☐	☐	☐
2			Moerig, Rainer et al.	☐	☐	☐	☐	☐	☐	☐
3	367/41; 367/43		Fleure, Thomas John	☐	☐	☐	☐	☐	☐	☐
4	706/16; 706/25		McCormack, Michael D. et al.	☐	☐	☐	☐	☐	☐	☐
5	181/108; 181/113; 367/190; 367/38; 367/40; 367/41		Andersen, Kenneth D.	☐	☐	☐	☐	☐	☐	☐
6	367/20; 367/904		Dragoset, Jr., William H.	☐	☐	☐	☐	☐	☐	☐
7	367/40; 367/48		Landrum, Jr., Ralph A.	☐	☐	☐	☐	☐	☐	☐
8	367/41; 367/49; 367/51; 367/60; 367/74		Edwards, Charles M.	☐	☐	☐	☐	☐	☐	☐
9	367/60		Edwards, Charles M. et al.	☐	☐	☐	☐	☐	☐	☐
10	367/60		Edwards, Charles M. et al.	☐	☐	☐	☐	☐	☐	☐
11	367/189; 367/68		Farr, John B. et al.	☐	☐	☐	☐	☐	☐	☐

	Image Doc. Displayed	PT
1	US 20030163260	☐
2	US 20020091487	☐
3	US 6418079	☐
4	US 5742740	☐
5	US 5410517	☐
6	US 4809235	☐
7	US 4715020	☐
8	US 4202048	☐
9	US 4201972	☐
10	US 4188611	☐
11	US 3678454	☐

US005586082A

United States Patent [19]

Anderson et al.

[11] Patent Number: 5,586,082

[45] Date of Patent: Dec. 17, 1996

[54] **METHOD FOR IDENTIFYING SUBSURFACE FLUID MIGRATION AND DRAINAGE PATHWAYS IN AND AMONG OIL AND GAS RESERVOIRS USING 3-D AND 4-D SEISMIC IMAGING**

[75] Inventors: **Roger N. Anderson; Albert Boulanger, both of New York, N.Y.; Edward P. Bagdonas, Brookline, Mass.; Liqing Xu; Wei He, both of New Milford, N.J.**

[73] Assignee: **The Trustees of Columbia University in the City of New York, New York, N.Y.**

[21] Appl. No.: **398,371**

[22] Filed: **Mar. 2, 1995**

[51] Int. Cl.^{6} **G01V 1/13; G01V 1/28**

[52] U.S. Cl. **367/73; 367/38; 367/59; 364/421**

[58] Field of Search 367/37, 38, 59, 367/73; 364/421; 382/22

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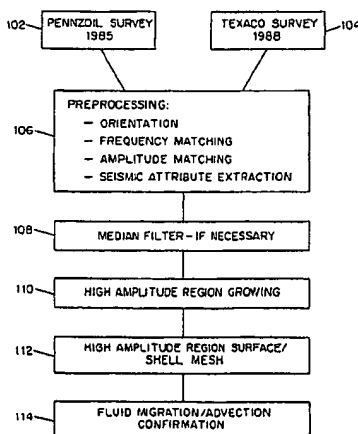
(List continued on next page.)

Primary Examiner—Nelson Moskowitz
Attorney, Agent, or Firm—Brumbaugh, Graves, Donohue & Raymond

[57] **ABSTRACT**

The invention utilizes 3-D and 4-D seismic surveys as a means of deriving information useful in petroleum exploration and reservoir management. The methods use both single seismic surveys (3-D) and multiple seismic surveys separated in time (4-D) of a region of interest to determine large scale migration pathways within sedimentary basins, and fine scale drainage structure and oil-water-gas regions within individual petroleum producing reservoirs. Such structure is identified using pattern recognition tools which define the regions of interest. The 4-D seismic data sets may be used for data completion for large scale structure where time intervals between surveys do not allow for dynamic evolution. The 4-D seismic data sets also may be used to find variations over time of small scale structure within individual reservoirs which may be used to identify petroleum drainage pathways, oil-water-gas regions and, hence, attractive drilling targets. After spatial orientation, and amplitude and frequency matching of the multiple seismic data sets, High Amplitude Event (HAE) regions consistent with the presence of petroleum are identified using seismic attribute analysis. High Amplitude Regions are grown and interconnected to establish plumbing networks on the large scale and reservoir structure on the small scale. Small scale variations over time between seismic surveys within individual reservoirs are identified and used to identify drainage patterns and bypassed petroleum to be recovered. The location of such drainage patterns and bypassed petroleum may be used to site wells.
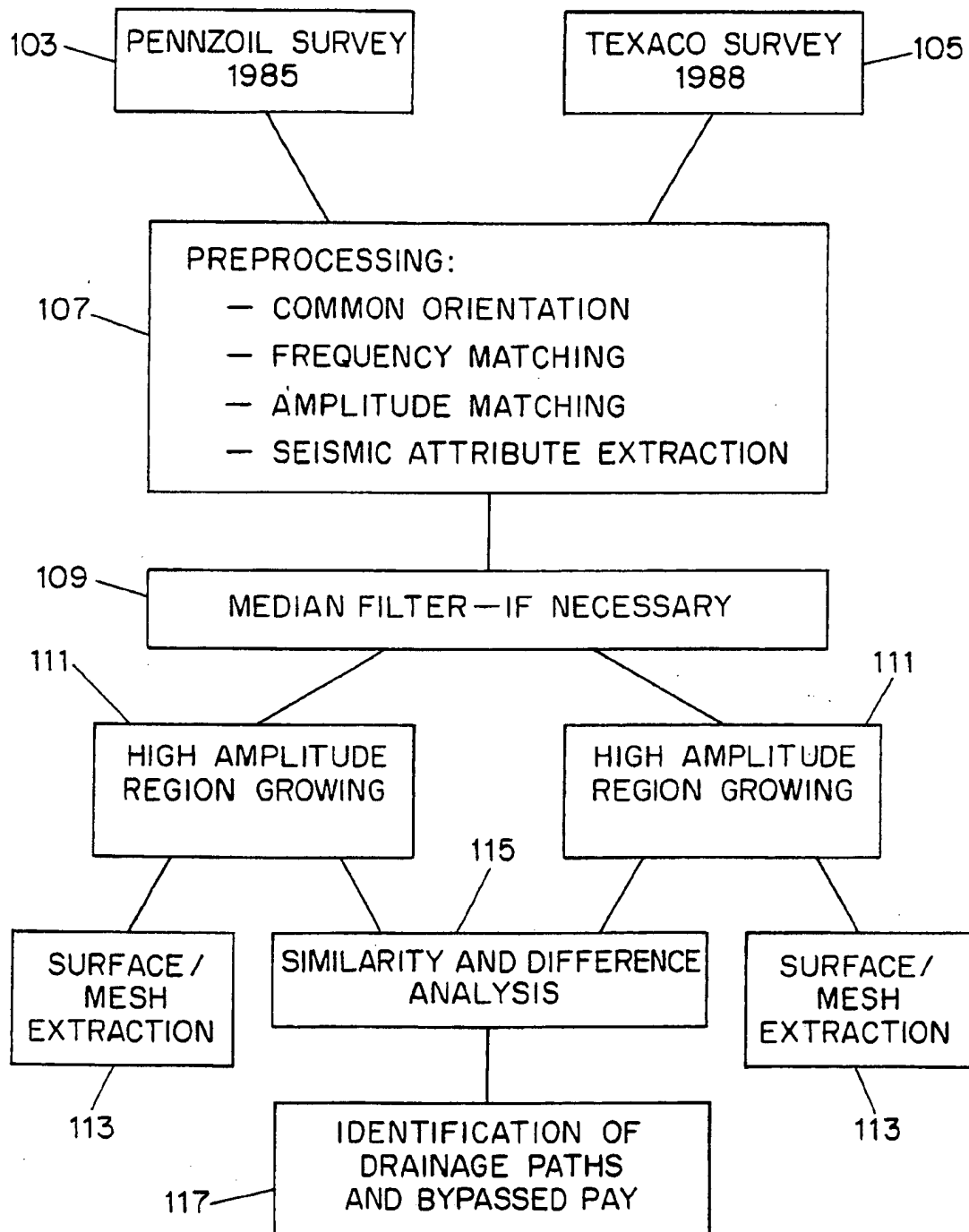
19 Claims, 17 Drawing Sheets

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103 ── PENNZOIL SURVEY        TEXACO SURVEY ──105
         1985                    1988
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PREPROCESSING:
107 ──
  — COMMON ORIENTATION
  — FREQUENCY MATCHING
  — AMPLITUDE MATCHING
  — SEISMIC ATTRIBUTE EXTRACTION

109 ── MEDIAN FILTER — IF NECESSARY

111 ── HIGH AMPLITUDE REGION GROWING   HIGH AMPLITUDE REGION GROWING ── 111

115

SURFACE / MESH EXTRACTION   SIMILARITY AND DIFFERENCE ANALYSIS   SURFACE / MESH EXTRACTION

113   117 ── IDENTIFICATION OF DRAINAGE PATHS AND BYPASSED PAY   113

FIG. 1B